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EFFECT OF INFILL STIFFNESS ON SEISMIC PERFORMANCE OF MOMENT RESISTING RC STRUCTURE

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ABSTRACT

The study investigates the overall seismic performance of the building due to different types of brick infill by linear time history analysis under the selected earthquake ground motion. The parametric study includes ground motion, strength of the infill walls expressed in terms of different types of bricks like AAC bricks, clay bricks and fly ash bricks. The results output are presented in terms of roof displacement, inter story drift, story shear of the structure. For different types of infilled structure, the analysis indicates that the stiffness of the infill structure increases as the compressive strength of the bricks increases. Further the analysis has shown that Autoclaved Aerated Concrete (AAC) blocks has more advantage than other bricks as it is light in weight, low strength, low stiffness and has high energy dissipation capacity. So it improves the overall seismic performance of in filled frames.

Key words: infill structure, ground motion, linear time history analysis, dissipation capacity.

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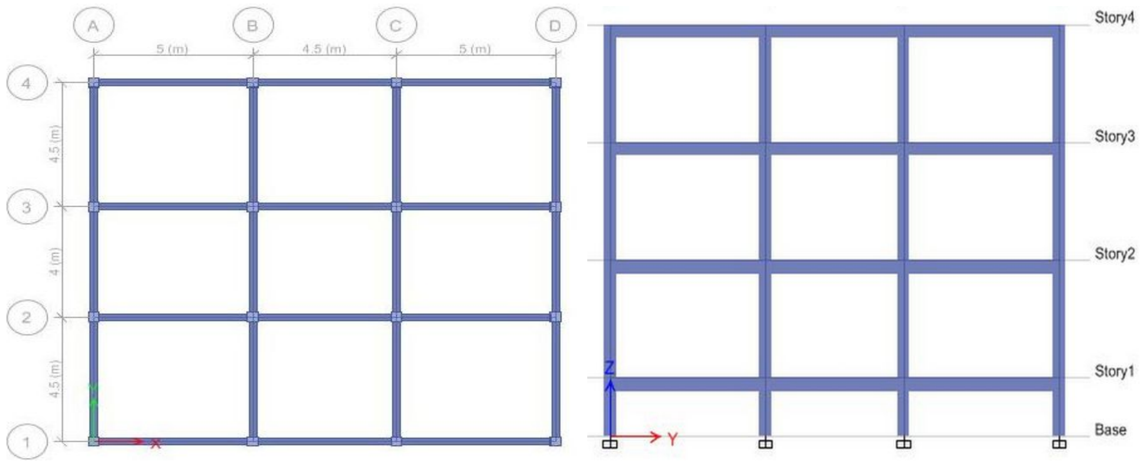
1. INTRODUCTION

The common practice in civil engineering considers the infill as nonstructural element thus they are often neglected in the evaluation of seismic behavior and overall performance of the structure. For the low and medium high rise building, the infilled reinforced concrete frame is mostly used all over the world. The infill walls are used as partition walls, cladding purpose and for external infill walls. A combination of in-plane and out-of-plane damage in unreinforced masonry bearing walls and infill walls in RC building contributed to the complete collapse of many buildings in recent Nepal earthquake[1] both in urban as well as rural areas. (Nepal Earthquake Reconnaissance Team, 2016).

Catalan et al. [2] studied selection and scaling of earthquake records in assessment of structures in low-to-moderate seismicity zones. The author emphasize the importance of the period T used for scaling Sa (T) for low and high level of structural performance. The authors have recommended to use 1.1 times the fundamental period of the structure, i.e. T=1.1T1. C.B Haselton et. al.[3]studied on selecting and scaling earthquake ground motions for performing response-history analyses to improve guidance to the earthquake engineering profession performing nonlinear response time history analysis such as in the level of ground motion, definition of the target spectrum, period range for scaling ground motions and ground motion scaling method. D. Jigme & Thambitratnam D.P. [4] studied on seismic response of the in filled structures. The author has found out that inter story drift, fundamental period, stress in the infill walls increases with the increase in the young's modulus of elasticity values and as the opening size of the infill increases. The author found out that the infill thickness has influence on the member forces moments and shears are significant. MorfidisK & KostinakisK [5] studied the role of masonry infills on the damage response of 80 bidirectional RC buildings subjected to seismic sequences. The results reveal that the influence of successive earthquake on the structural damage is larger for the in filled buildings compared to the bare structures.

2. MODELING AND ANALYSIS OF INFILLED FRAMES

Three storied ordinary residential reinforced concrete moment resisting frame with plan dimension of 14.5 mx13 m is considered as the prototype structure as shown in Figure 1. It is design as per IS 456:2000[6] and IS 1893:2002 [7].The limit state design concept has been used to extent the structural members. The concrete material with young modulus 20MPa and poisons ratio of 0.2 is considered for the design. A TMT bar of specified yield strength 415MPa was used for reinforcement. The density of the brick masonry and concrete was considered as 19kN/m^3 and 25kN/m^3 which will be used for the seismic weight calculation. The live load assumed is 2kN/m^3 for floor level slab and 1.5kN/m^3 for roof floor slab. The sources of structural mass are from the structural members like beam, column and slabs, etc. The prototype structure was modeled with different types of infill material with the aid of ETABS software [8]. The cross-section of the beam is 350 x250 mm and column size of 350 x 350 mm is satisfactory for the three storied structure.



(a) Three Storied Building Plan **(b)** Elevation of three Storied Building

Figure 1 Geometry of RC building Model

For the infill material properties for different types of bricks, the experimental brick prism test was done by Durgesh C. Rai [9],[10] and their members from IIT Kanpur. The modulus of elasticity obtained are 4200 MPa, 2327 MPa and 3600MPa for fly ash, AAC and clay bricks respectively. The stress strain values with different control points are given below:

Table 1 The Stress Strain Values for Different Types of Bricks

	Fly Ash Bricks		**AAC Bricks**		**Clay Bricks**	
Stress Level	Stress(MPa)	Strain	Stress(MPa)	Strain	Stress(MPa)	Strain
0.75fm’	5.498	0.00098	0.575	0.00009	2.918	0.00177
1fm’	7.33	0.00297	1.149	0.00051	3.89	0.00546
0.2fm’	1.466	0.00817	0.345	0.00948	0.778	0.01503

3. LINEAR TIME HIISTORY ANALYSIS

3.1. Selections of Ground Motions

The four ground motions selected are shown below:

Table 2 Earthquake Ground Motion Properties

Sl. No	Earthquake Name/Region	Station Name	Date	Magnitude	PGA (g)
1	Imperial Valley(USA) Earthquake	GSGS STATION 5115	15^{th}October,1979	6.4 Mw	0.30
2	Kobe (Japan) Earthquake	KAKOGANA(LUE 90)	16^{th}January,1995	6.9Mw	0.35
3	Landers(USA) Earthquake	000SCE STATION 24	28^{th} June, 1992	7.3Mw	0.74
4	Kocaeli (Turkey) Earthquake	YARIMCA(KOERI330)	17^{th}August,,1999	7.6Mw	0.31

3.2. Scaling of Ground Motion

Before the selection of the ground motion, the static analysis of the structure was done. For the static analysis, the building is assumed in high seismic zone V with medium soil type II, response reduction R 3 and importance factor I equal to 1. The time period of the structure is found out and it's used for the scaling of the ground motion. The next important step was matching of the time history acceleration with target response spectrum and we have selected IS1893:2002, Indian standard criteria for earthquake resistant design of structures as target response spectrum. As per the code, accelerogram is considered to be compatible with a given design spectrum if the 5% damped response spectrum of the accelerogram is close to the design spectrum within a specified period range, which is usually referred to as the period range of interest. As per the code ASCE [11], it states that the scaled time history has to be greater than target response spectrum from 0.2T to 1.5T where T is the fundamental period of the building for the direction of the response being analyzed. After taking care of the rules and guidelines, the first matching was done with frequency domain but there was not proper matching of the spectral values for all the models of the structure. Finally, the spectral matching was done with time domain for all the models of the structure. The scaled accelerogram for Imperial Valley earthquake was 1.05g, 0.91g for Kobe earthquake, 1.10g for landers earthquake and 0.82g Kocaeli earthquake as shown in Figure 2,3,4,5 & 6.

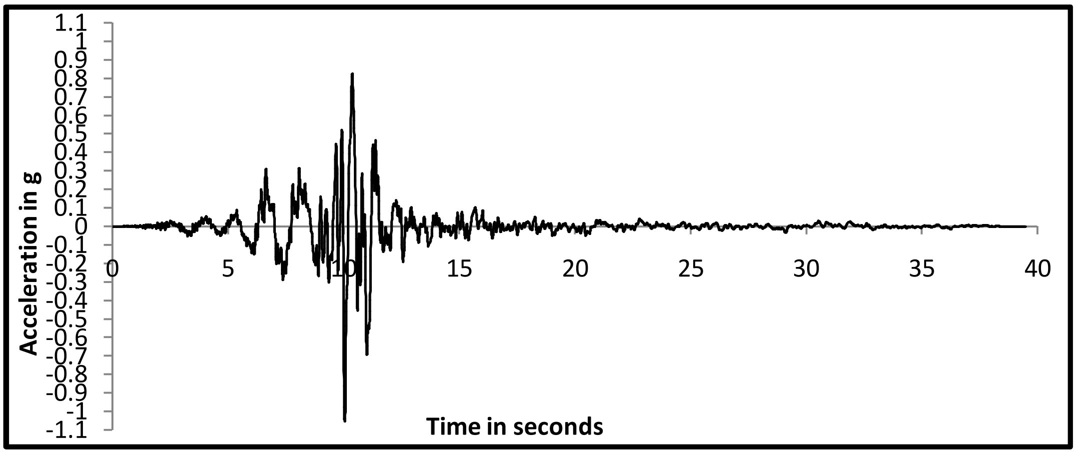


Figure 2 Scaled Imperial Valley (USA) Earthquake, 15th October, 1979.

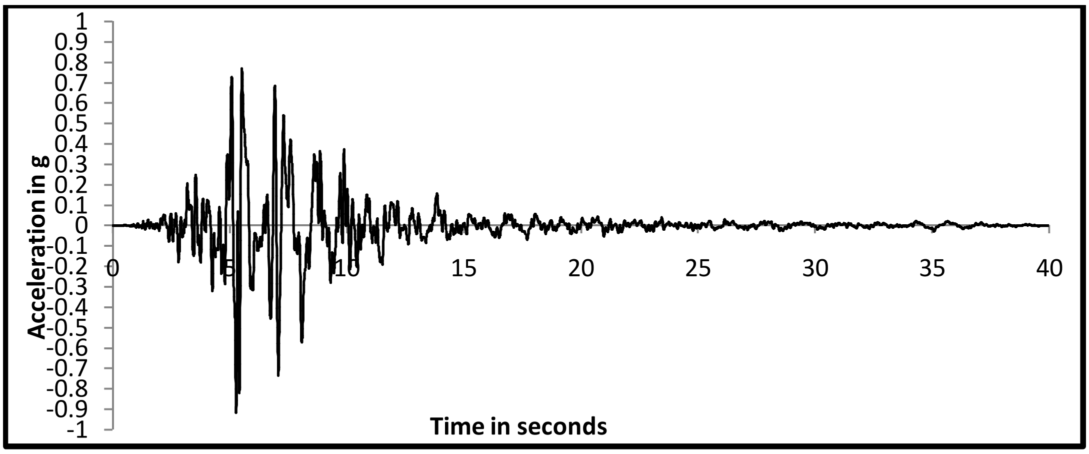


Figure 3 Scaled Kobe Earthquake Ground Motion, 16th January, 1995

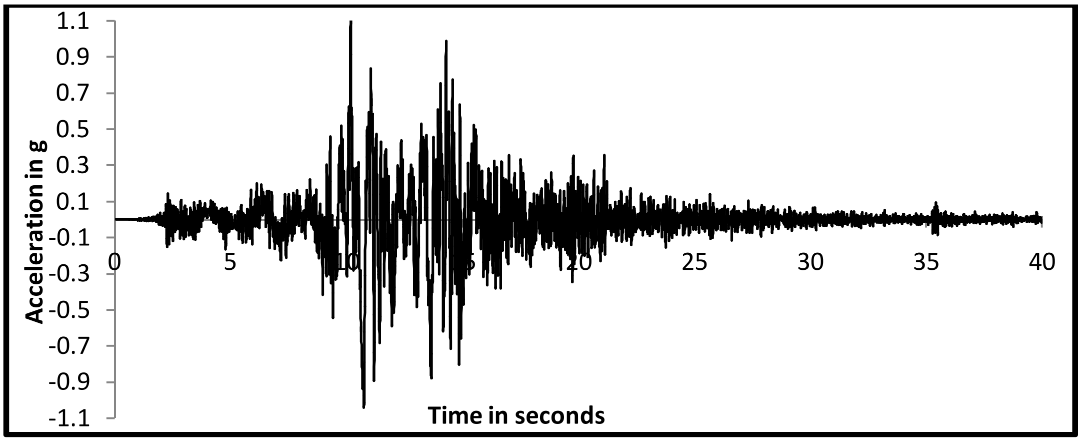


Figure 4 Lander Earthquake Ground Motions, 28thJune, 1992

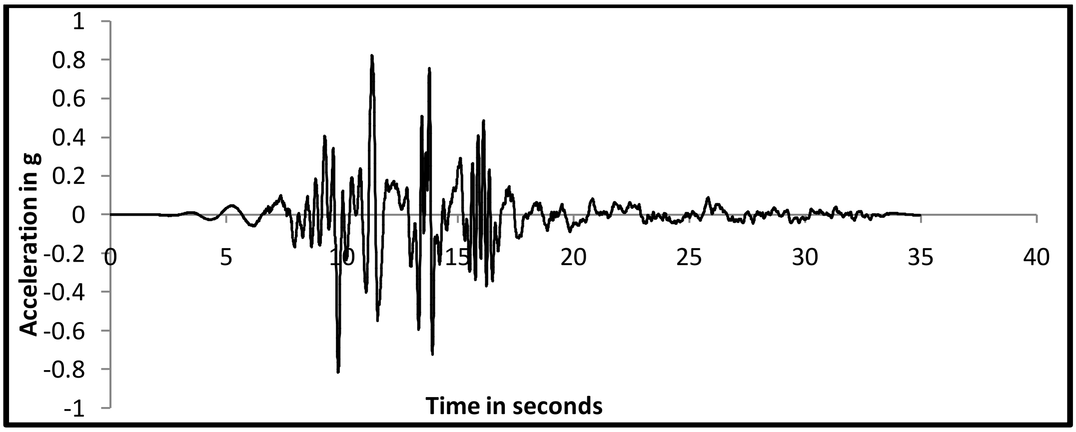


Figure 5 Kocaeli (Turkey) Earthquake Ground Motion, 17th August, 1999

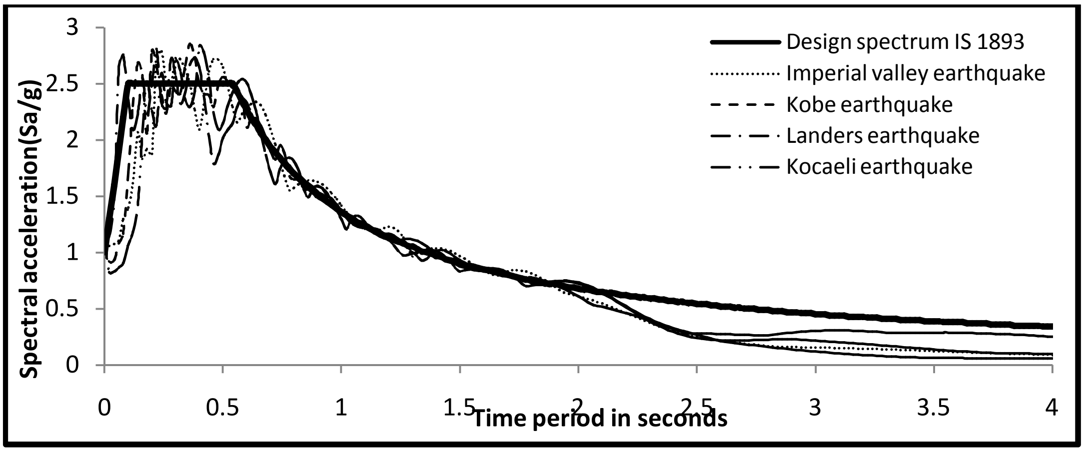


Figure 6 Design Spectrum with Scaled Ground Motion.

4. EFFECTS OF DIFFERENT TYPES OF BRICK INFILL: RESULTS

4.1. Displacement

The seismic displacement of three storied building with three different types of bricks and with different ground motions are shown in the Figure 7, 8, 9&10respectively. Here we have found displacement of the structure at each floor level and displacement (mm) is shown in X axis and height of structure (m) in Y axis. From Imperial Valley ground motion, the maximum displacement was 3.79 mm in X direction and 4.06 mm in Y direction from clay

bricks. The AAC bricks have more resistant against lateral force of the ground motion and has maximum displacement of 0.92 mm and 1.18 mm in X and Y direction. From Kobe earthquake ground motion, the maximum displacement was 3.72 mm and 4.04mm obtained from clay bricks. The AAC bricks has more resistant towards later force and has maximum displacement of 1.04 mm and 1.11 mm in X and Y direction respectively. From landers earthquake ground motion, the maximum displacement was 3.62 mm and 3.94 mm in X and Y direction respectively. Similarly the AAC bricks has more resistant towards the earthquake lateral force and has displacement of 0.94 mm and 1.055 mm in X and Y direction. From Kocaeli earthquake ground motion, we have maximum displacement of 3.49 mm and 4.04 mm in X and Y direction. The AAC bricks has more resistant towards the lateral force and has the displacement of 1.01 mm and 1.053 mm in X and Y direction respectively.

Overall in X direction AAC bricks has highest resistant against the lateral force and has maximum displacement of 0.92 mm at the time of 19.53 seconds from the Imperial Valley earthquake ground motion. Similarly for Y direction AAC bricks have maximum displacement of 1.053 mm at the time 28.29 seconds from Kocaeli earthquake ground motion.

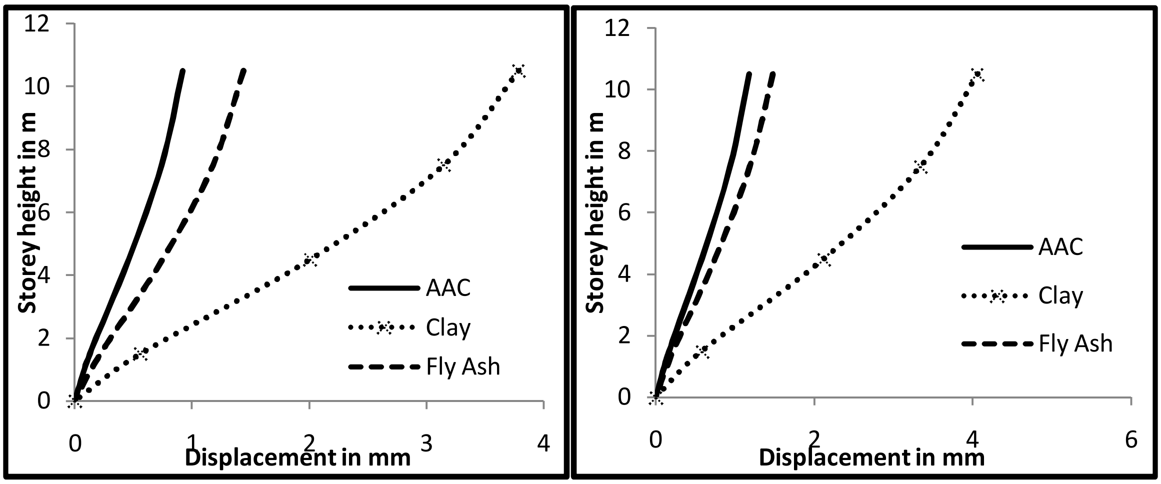


Figure 7 The Imperial Valley earthquake ground motion displacements in X & Y direction

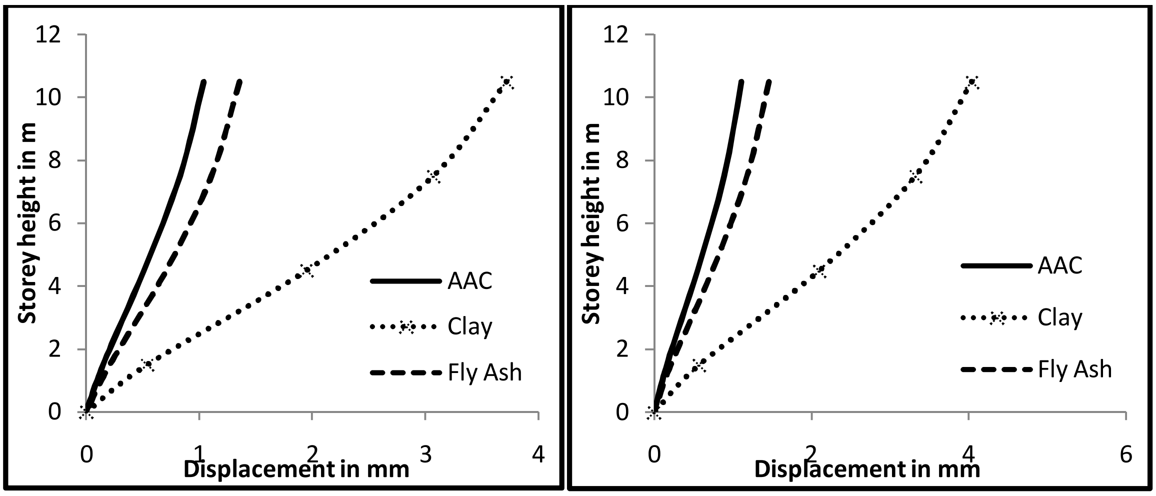


Figure 8 The Kobe earthquake ground motion displacement in X & Y direction

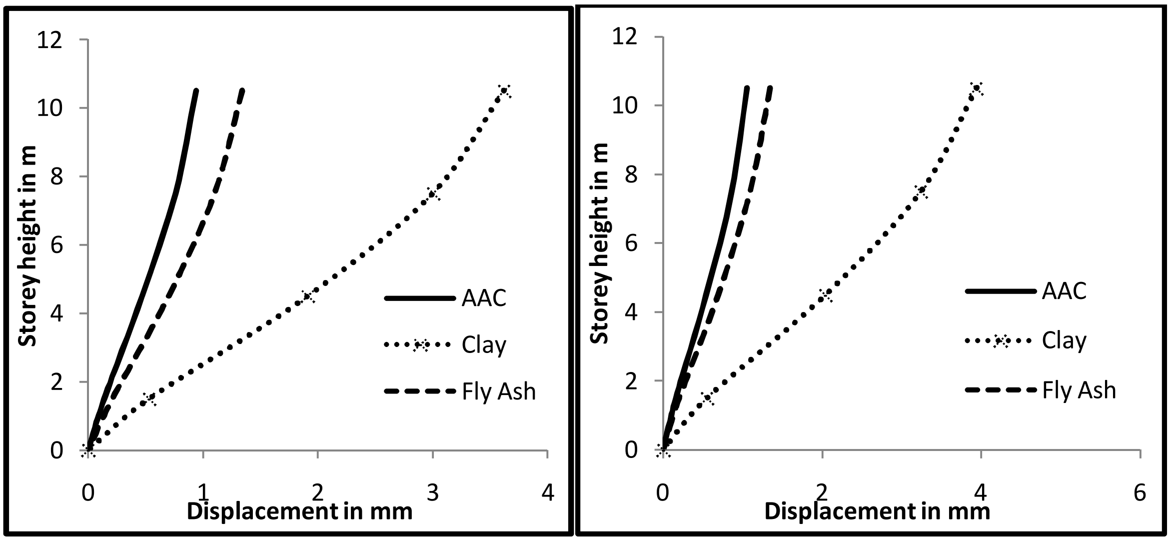


Figure 9 The Landers earthquake ground motion displacement in X & Y direction

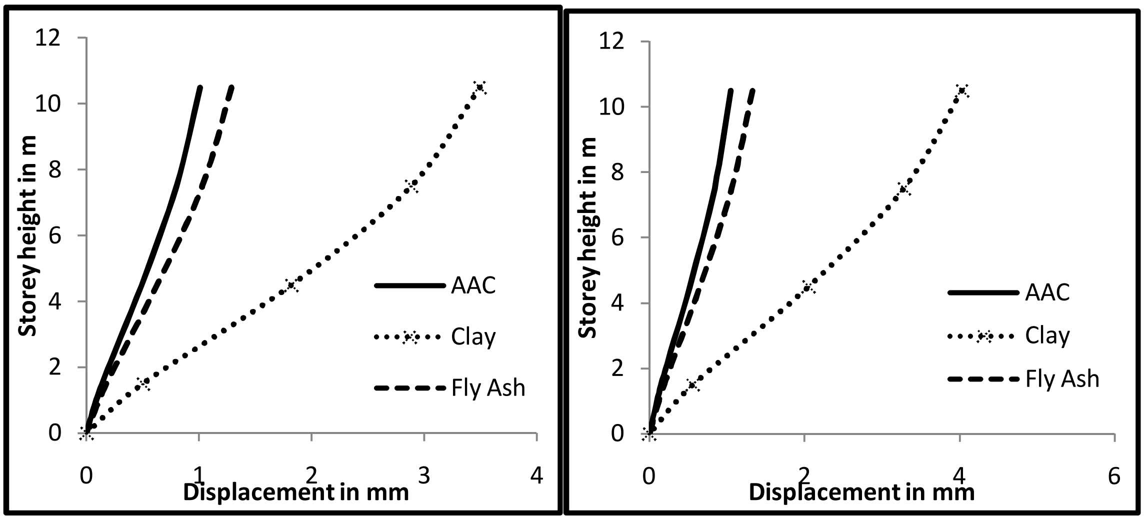


Figure 10 Kocaeli earthquake ground motion displacements in X & Y direction

4.2. Inter Storey Drifts Ratio

The seismic inter storey drift of three storied building with three different types of bricks and different ground motions are shown in the Figure11, 12, 13 & 14respectively. From all the ground motion, it was observed that clay bricks experiences the maximum drift ration across the height of the structure. The maximum drift ratio of 0.0036 was obtained from clay bricks under Kobe earthquake ground motion. The inter storey drift limit of the existing code (IS 1893, 2002) is 0.004 and the drift ratio of all types of bricks under different ground motion did not exceed the code limit.

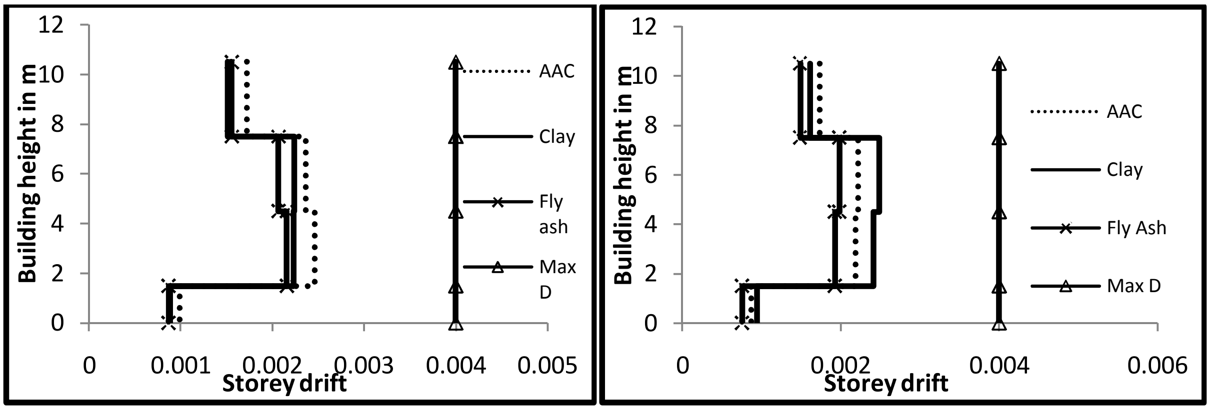


Figure 11 The Imperial Valley earthquake ground motion storey drift ratio in X & Y direction

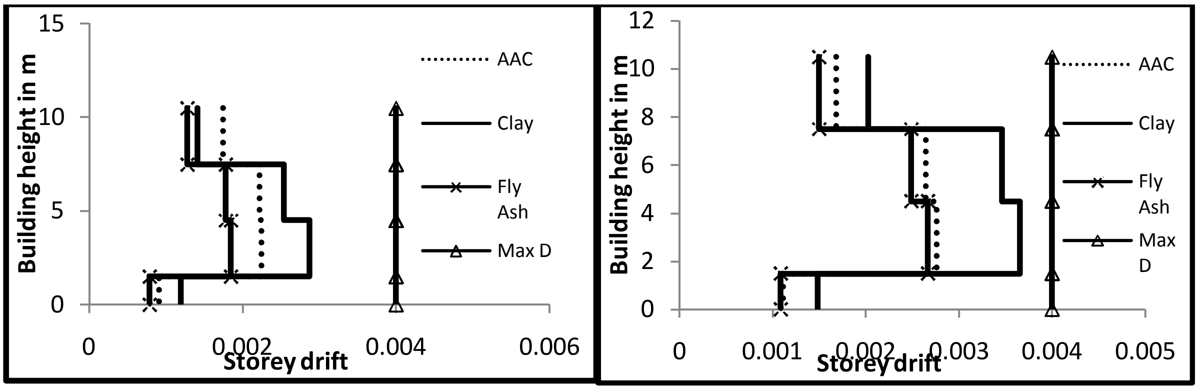


Figure 12 The Kobe earthquake ground motion storey drift ratio in X & Y direction

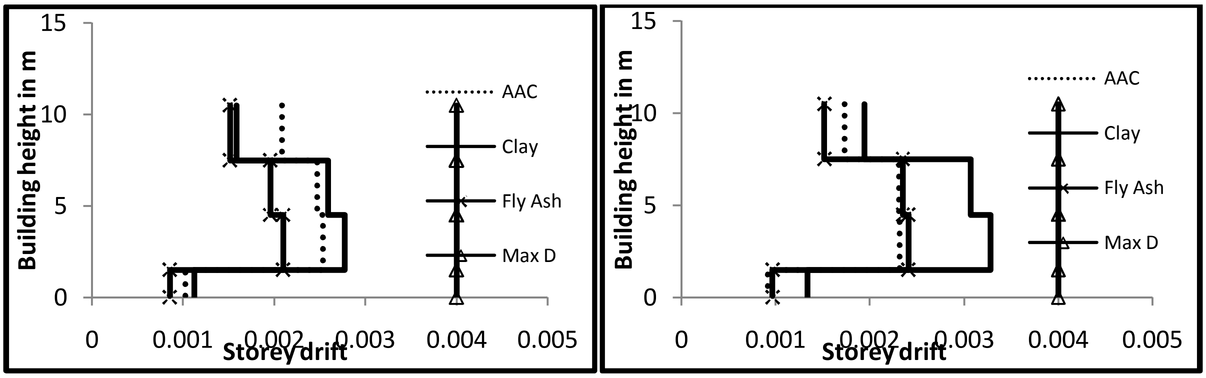


Figure 13 The Landers earthquake ground motion storey drift ratio in X & Y direction

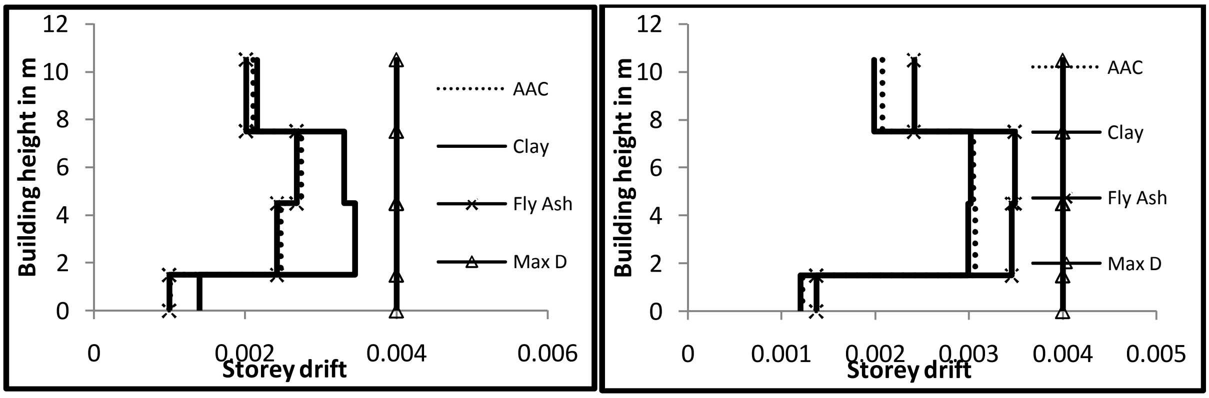


Figure 14 Kocaeli earthquake ground motion storey drift ratio in X & Y direction

4.3. Storey Shear

The inter storey shear of three storied building with three different types of bricks and different ground motions are shown in the figure 15, 16, 17 & 18 respectively. From Imperial Valley ground motion, the maximum shear of 1876 kN was obtained from fly ash bricks in X direction and maximum base shear was 1740 kN in Y direction from fly ash bricks. From Kobe earthquake ground motion, maximum base shear of 1849 kN was obtained from fly ash bricks in X direction and 1727 kN from Y direction from clay bricks. From Landers earthquake ground motion, maximum base shear of 1883 kN was obtained from fly ash bricks in X direction and 1746 kN from Y direction from fly ash bricks. From Kocaeli earthquake ground motion, maximum storey base shear of 1714 kN was obtained from fly ash bricks in X direction and 1806 kN from Y direction from clay bricks. The overall highest storey shear among different types of bricks was obtained from fly ash bricks with base shear of 1883kN from landers earthquake ground motion in X direction and clay bricks with base shear of 1806 kN from Kocaeli earthquake ground motion in Y direction.

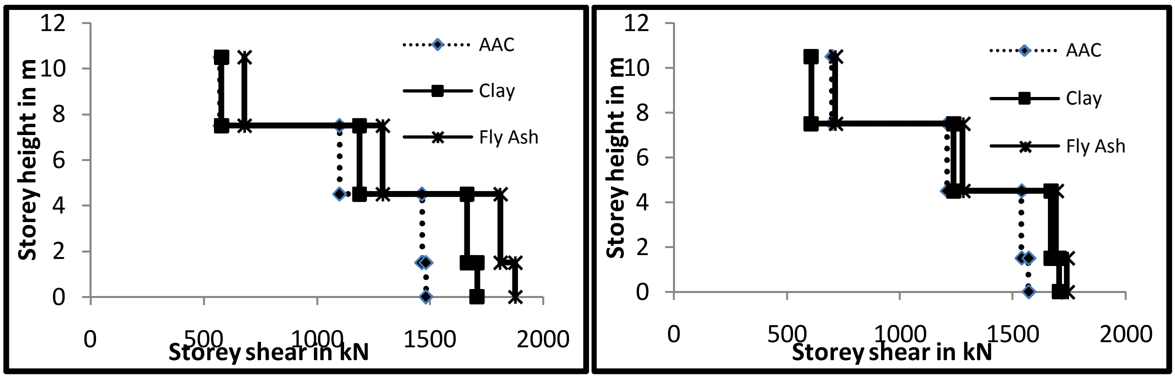


Figure 15 The Imperial Valley earthquake ground motion storey shear in X & Y direction

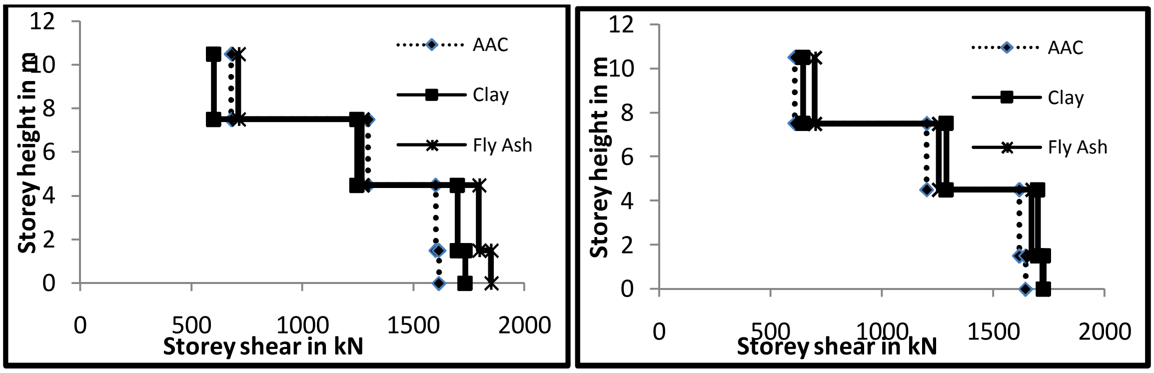


Figure 16 The Kobe earthquake ground motion storey shear in X & Y direction

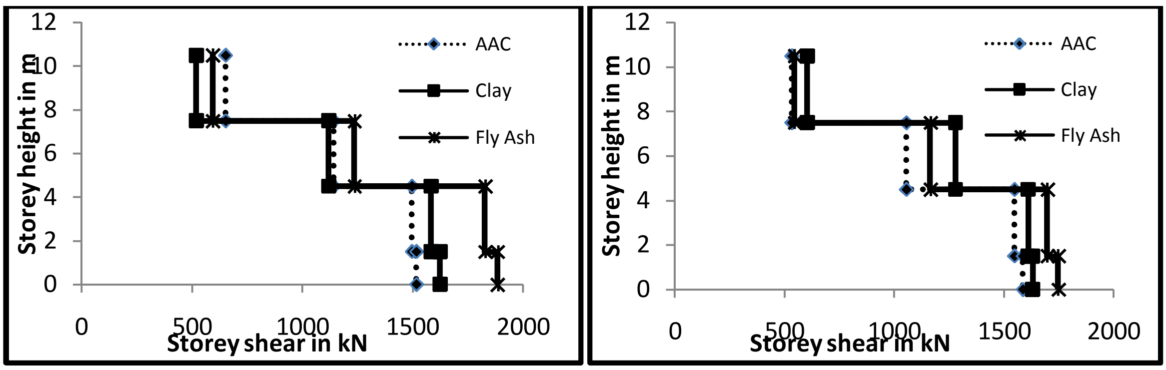


Figure 17 The Landers earthquake ground motion storey shear in X & Y direction

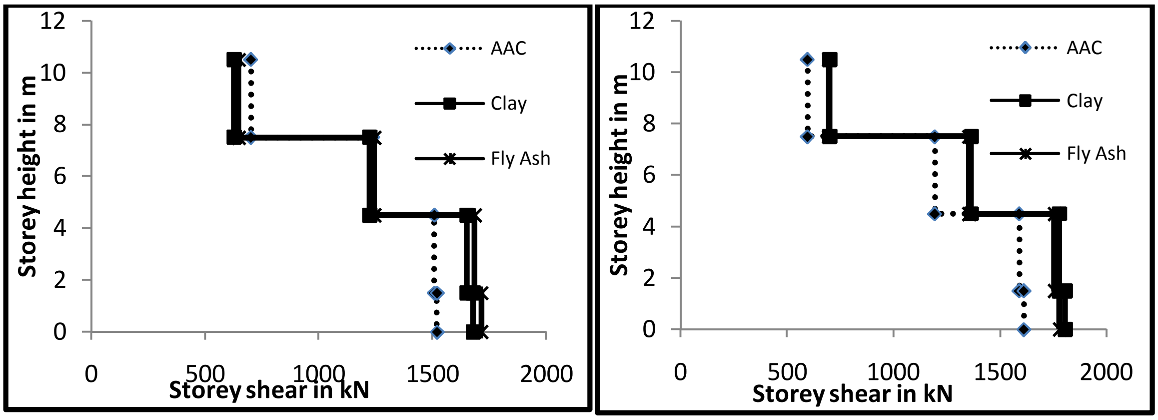


Figure 18 Kocaeli earthquake ground motion storey shear in X & Y direction

5. CONCLUSION

- AAC bricks has highest resistant against the lateral force than the clay bricks and fly ash bricks for both X and Y direction from all four ground motion. The low strength, low unit weight and low stiffness of AAC masonry results in improved load sharing between the infill and the frame. Therefore AAC masonry infill has the highest energy dissipation capacity.
- The inter storey drift limit of the existing code, IS 1893:2002 is 0.004 and the drift ratio for all types of masonry infill under different ground motion did not exceed the code limit. This indicates the influence of infill on the lateral deformation of the structure. Thus infill walls should be considered for the seismic design of the building and should not be neglected.
- Since the unit weight and the compressive strength was more for the fly ash bricks, the fly ash bricks experiences the highest storey shear in both the direction which accumulates more energy for displacement of the structure. The building with infill has enough redundancy to resist earthquake force if proper material is used issued for the infill walls.
- The strength of infill has a significant role in the global performance of the structure. The structural response such as roof displacement, inter storey drift and storey shear decrease with the increase in modulus of elasticity values. Thus it is important to choose the right material for the infill and consider it in analysis and design.

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